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Reading for meaning: What influences paragraph understanding in aphasia?

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Title: Reading for meaning: What influences paragraph understanding in aphasia?

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Short Title: Reading in aphasia

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Abstract

Purpose: The current study investigated the effect of text variables including length, readability, propositional content and type of information on the reading comprehension of people with aphasia.

Method: The performance of 75 people with aphasia was compared to 87 healthy, age-matched control participants. Reading comprehension was considered in terms of both accuracy in responding to questions tapping comprehension and reading time. People with aphasia were divided into two groups (no reading impairment PWA: NRI, reading impairment PWA: RI) depending on whether their performance fell within the 5th percentile of control participants.

Results: As groups, both PWA: NRI and PWA: RI differed significantly from control participants in terms of both reading time and comprehension accuracy. PWA: NRI and PWA: RI differed from each other in terms of accuracy but not reading time. There was no significant effect of readability or propositional density on comprehension accuracy or reading time for any of the groups. There was a significant effect of length on reading time but not on comprehension accuracy. All groups found main ideas easier than details, stated information easier than inferred and had particular difficulty with questions that required integration of information across paragraphs (gist).

Conclusions: Both accuracy of comprehension and reading speed need to be considered when characterising reading difficulties in people with aphasia.

Background

Reading for meaning is an everyday activity, a key part of our participation in a range of social, leisure and work activities (Parr, 1995, 1996; Smith, 2000). People with aphasia frequently report reading difficulties, with problems understanding single words, sentences and/or extended text, with oral reading and/or reduced reading speed (Knollman-Porter, Wallace, Hux, Brown, & Long, 2015; Samouelle, 2013). Reading difficulties can result in reduced participation in activities (Knollman-Porter et al., 2015; Parr, 1995), potentially leading to a reduced quality of life (Parr, 2007; Rose, Worrall, Hickson, & Hoffmann, 2011). Brookshire and colleagues (Brookshire, Wilson, Nadeau, Rothi, & Kendall, 2014) reported 68% of people with aphasia experience reading difficulties (using criteria based on oral reading). Webb and Love (1983) suggested reading difficulties are integral to aphasia, reporting that all of their (chronic) participants had residual reading comprehension difficulties. Despite the reported prevalence of reading difficulties, we understand surprisingly little about reading for meaning in aphasia, particularly for more extended

text. This study compares the reading performance of people with aphasia and healthy readers, manipulating aspects of the text to investigate how these influence comprehension.

Spoken and Written Discourse Comprehension in Healthy Readers

In considering comprehension of paragraphs (or discourse) in aphasia, it is important to consider what is understood about discourse comprehension in healthy readers. Discourse comprehension refers to understanding beyond the sentence level, with research often drawing on comprehension of both spoken and written material. Clearly written discourse comprehension is a complex process with several factors known to influence reading ability and preferences in healthy readers. Factors include person-related variables, for example, age (e.g., Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine, 1990), social background (e.g., Gleed, 2014), level of education and factors related to the capacity and efficiency of cognitive processes, for example, attention, memory (e.g., Carretti, Borella, Cornoldi, & De Beni, 2009; Just & Carpenter, 1992) . Reading ability, in terms of both reading accuracy and reading speed, can also be influenced by the nature of the text; the current study will focus on the influence of text related variables.

Kintsch (1988) proposed a model for discourse comprehension (including spoken and written) involving construction and integration of material, with discourse organised on the basis of macro-structure and microstructure. Macrostructure is the coherent organisation of the main ideas or themes within the discourse. Microstructure is the surface structure of sentences, including the individual words and propositions. Within discourse comprehension, we need to understand the words and sentences, construct the meaning of the text as a whole and then relate the information to our knowledge of the world. This requires a complex interaction between linguistic and other cognitive processes, for example, attention, working memory, episodic memory and executive function.

In Kintsch's construction-integration model, within the construction phase, the linguistic form is processed, propositions are identified and inferences made. A proposition is defined as 'the smallest unit of knowledge that can stand alone; it has a truth value – that is, a proposition can be either true or false' (Harley, 2008, p379). Propositions include the verb and its arguments, adjectives, adverbs, prepositions and conjunctions (Brown, Snodgrass, Kemper, Herman, & Covington, 2008). During text processing, propositions are extracted from the text and then organised according to the arguments they share. The main ideas within the text are repeated across propositions and form the macrostructure. Details related to the main ideas are not repeated and form the microstructure. In coherent text, the details must be related to one another and to the main idea. Within Kintsch's model, the construction

phase is followed by an integration phase, where information is integrated into a coherent whole and ambiguous or incorrect inferences are resolved. This involves going back to information that has already been specified, that is, to the network of propositions that is already built and stored in episodic memory and to their general knowledge of the world. 'We construct the intended message from what is explicitly stated, together with both general and specific background knowledge' (Oakhill & Garnham, 1988, p22). Following comprehension, when we remember and recall text, we focus on the overall meaning of the passage not the exact words or sentences used. Memory and recall is influenced by the relative importance of information with better recall of ideas that are more prominent/important (e.g., Johnson, 1970; Kintsch & Van Dijk, 1978).

Within discourse comprehension, meaning may be present within the text or may need to be inferred. Harley (2008) describes inference as 'the derivation of additional knowledge from facts already known; this might involve going beyond the text to maintain coherence or to elaborate on what was actually presented' (p368). Harley identifies three types of inference: logical, bridging and elaborative. Logical inference arises from word meaning. Bridging inferences link new information to earlier information, thereby maintaining coherence. Elaborative inferences are made when we extend what is in the text using world knowledge. As we focus on overall meaning and discard sentence structure when we remember text, it can be difficult to distinguish what we directly hear from the inferences we subsequently make.

As discussed above, propositions are the main units involved in the initial understanding and organisation of text and research has considered the influence of the propositional density of text. Kintsch and Keenan (1973) reported that the more propositions there are in a written passage, the longer it takes to read per word, with the increased reading time (for texts with higher propositional density) reflecting the time taken to extract the propositions. Higher level (superordinate) propositions repeated and elaborated during comprehension are more likely to be remembered during free recall (Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975). Related to this, questions related to main ideas (central information which is repeated and elaborated) are answered more accurately than questions related to details (peripheral information which is stated only once) (Brookshire & Nicholas, 1984, 1993; Wegner, Brookshire, & Nicholas, 1984). The distinction between main ideas and details conveys the relative importance of the information within the broader text. When main ideas and details are linked, the text is coherent. Just and Carpenter (1977) proposed that coherence provides linguistic cues for integrating sentences into larger units, facilitating memory. Coherence may, therefore, compensate for limitations in memory and processing

capacity. Research shows that when passages are scrambled in terms of order, and therefore not globally coherent, they take longer to read as readers have to reorganise them. Reading is also influenced by the explicitness of information; passages including inferences take more time to read than those with no inference and, if incorrect inferences are drawn, this will slow reading as these are corrected in the light of later information (Ellis, 1993).

Discourse can differ in many ways and, within the study of reading, there has been a longstanding interest in how the complexity of text can be described and quantified. Readability measures attempt this quantification and have focused on either the semantic and syntactic features of the text (classic readability formulas) or the cognitive and organisational features (cognitive-structural measures) (Chall & Dale, 1995). There are a large number of classic readability formulas, for example, Dale-Chall (Chall & Dale, 1995; Dale & Chall, 1948) and Flesch-Kincaid (Kincaid, Fishburne Jr, Rogers, & Chissom, 1975); these differ in terms of the exact parameters they use to grade the text. The Dale-Chall Readability formula (Chall & Dale, 1995; Dale & Chall, 1948) assigns grade levels to written text based on a calculation that considers mean sentence length and the number of unfamiliar words. This readability formula therefore takes into account both word familiarity and syntactic complexity. It offers a rapid (though possibly inexact) measure of relative difficulty across texts and has been used to consider text difficulty in a previous assessment of reading comprehension in people with aphasia (Discourse Comprehension Test (DCT), Brookshire & Nicholas, 1993).

Spoken and Written Discourse Comprehension in People with Aphasia

Information about discourse comprehension in people with aphasia has come predominantly from studies of spoken comprehension, providing some potential indicators of factors affecting written discourse. It has been suggested that the redundancy and context present in discourse can compensate for lexical and grammatical difficulties at word and sentence level (Brookshire & Nicholas, 1984; Stachowiak, Huber, Poeck, & Kerschensteiner, 1977; Waller & Darley, 1978). Although syntactic comprehension difficulties are common in people with aphasia, difficulties seen on sentence level assessments do not always impact comprehension of discourse. Some studies have shown a lack of relationship between performance on tests of sentence and discourse comprehension in both spoken comprehension (Brookshire & Nicholas, 1984; Waller & Darley, 1978; Wegner et al., 1984) and written comprehension (Meteyard, Bruce, Edmundson, & Oakhill, 2015). However, other studies have found a significant correlation between performance on tests of sentence and paragraph comprehension (Caplan & Evans, 1990;

Webster, Morris, Howard, & Garraffa, 2016) although dissociations may still be present in individual performance (Caplan & Evans, 1990).

Other investigations have considered what factors influence the comprehension of paragraph level discourse. Jones and colleagues (Jones, Pierce, Mahoney, & Smeach, 2007) showed that people with aphasia can answer questions about spoken paragraphs more accurately when they contain familiar content (in terms of names of people and places) and suggest that the beneficial effects may be due to improved attention and/or the effect of domain specific knowledge. As considered above (in relation to healthy readers), a number of studies have considered the effect of information importance (or information salience), contrasting the understanding of main ideas and details. Brookshire and Nicholas (1984) showed that the performance of people with aphasia resembled that of healthy participants in spoken comprehension; main ideas were understood significantly better than details. Later studies of auditory comprehension have confirmed this better understanding of main ideas (Wegner et al., 1984) and have shown that the location of the main idea within the discourse does not impact comprehension (Hough, 1990). Hough showed that comprehension was equivalent whether the main idea/theme occurred at the start of the text (as is normal) or if the introduction of the main idea was delayed until later in the discourse. Within the DCT (Brookshire & Nicholas, 1993), comprehension of both spoken and written comprehension is considered, with the same advantage for the comprehension of main ideas reported. Wegner et al. (1984) investigated whether the spoken comprehension of main ideas and details was affected by the coherence of the discourse. There was no impact of whether the discourse was coherent or noncoherent when understanding main ideas. Coherence did impact the comprehension of details, with different effects on the performance of people with aphasia and control participants. Control participants made fewer errors on details within coherent discourse; people with aphasia made fewer errors on non-coherent discourse. The authors suggest people with aphasia may have difficulty keeping semantically related ideas separate and thus non-coherent discourse with different themes and little relationship between the details may be easier. These findings suggest that people with aphasia may use main ideas in a similar way to normal listeners, searching for, identifying and integrating them to maintain the global coherence of the text (Wegner et al., 1984). Like normal readers, people with aphasia find details more difficult but there is some evidence that their linguistic difficulties may differentially impact their comprehension of more peripheral information that is not repeated.

Previous studies have also considered whether explicitness and the extent to which information is stated or needs to be inferred influences comprehension in people with aphasia. Brookshire and Nicholas (Brookshire & Nicholas, 1984, 1993) considered the effect of explicitness, contrasting directly or indirectly stated information. In the original study (Brookshire & Nicholas, 1984), explicitness did not significantly influence spoken comprehension. However in contrast, explicitness was shown to influence both spoken and written comprehension within the DCT (Brookshire & Nicholas, 1993), particularly for details; performance on directly stated information was better than indirectly stated (implied) information. Within other tests of reading comprehension, for example the Measure of Cognitive-Linguistic Abilities (MCLA, Ellmo, Graser, Krchnavek, Calabrese, & Haunch, 1995) and the Reading Comprehension Battery for Aphasia-2 (RCBA-2, Lapointe & Horner, 1998), there is a contrast between factual and inferential information. The MCLA is designed for use with people following traumatic brain injury and does not report data from people with aphasia. On the first edition of the RCBA, Van Demark, Lemmer, and Drake (1982) found that the factual reading sub-test was easier than the inferential sub-test, with a high level of agreement regarding relative difficulty across the 26 participants.

Meteyard et al. (2015) investigated inferential comprehension in four people with chronic aphasia who reported having adequate written single word and sentence comprehension but difficulty reading text. They investigated inferential comprehension by comparing factual versus inferential reading on the MCLA and using a specifically designed inference task contrasting understanding of local and global inferences. They define local inferences as those requiring interpretation based on links between successive words and sentences and global inferences as those needing integration of world knowledge (Meteyard et al., 2015). Varied patterns of reading comprehension difficulties were seen across the four participants, with different patterns of retained and impaired performance across factual and inferential reading and the understanding of local and global inferences. Meteyard et al. also considered the relationship between text comprehension and single word comprehension, sentence comprehension and cognitive skills. While it is hard to show associations in a study with just four participants, there was no straightforward relationship between text level reading and reading at single word and sentence level or between text level reading and a metacognitive skill (error detection). Impaired verbal working memory (as assessed by pointing span) was, however, associated with difficulty with global inferences. Chesneau and Ska (2015), in a study of five individuals with aphasia, also investigated the impact of attentional and memory demands, but found no straightforward relationship between cognitive performance and patterns of text comprehension. Their study

considered the impact of semantic load (number of details) and the extent to which people had to modify and update their understanding of a situation they were reading about e.g., they would read a passage about plane crash which they may subsequently read was in a dream. Varied patterns of comprehension were seen across the participants, with no consistent effect of semantic load or whether understanding required updating of the situational model.

Previous research has also considered the role of sentence complexity in spoken discourse comprehension. When sentences which are difficult to understand (e.g., reversible passives) are presented in a context where the characters and action are introduced, comprehension is better (Hough, Pierce, & Cannito, 1989). For some people with aphasia, comprehension improved whether or not the information pragmatically predicted the event, suggesting redundancy alone aided understanding. For other people, the context needed to be predictive of the situation, making one interpretation of the passive more plausible (Hough et al., 1989). Caplan and Evans (1990) investigated the influence of syntactic complexity on spoken discourse comprehension, with syntactic complexity varied without affecting the semantic content; sentences were non-reversible and could be understood via the lexical content. Within the study, neither control participants nor people with aphasia had greater difficulty with the syntactically complex stories compared to the simple stories although participants reported they were longer and harder to remember. The authors conclude 'in common discourse structures containing semantically and discourse constrained sentences, the syntactic complexity of the sentences in the discourse does not have an independent effect upon the aphasic patients' abilities to answer questions about the content of a passage, regardless of a patient's ability to comprehend sentences by a syntactic route' (p224). In contrast, Levy et al. (2012) found that when discourse contains sentences that are semantically reversible and syntactically complex (i.e., cannot be understood via lexical/contextual information), the comprehension of discourse is affected. Spoken discourse containing only simple sentences was understood more accurately than discourse containing some semantically reversible sentences with noncanonical word order (complex syntactic structures), with the effect present in both people with aphasia and control participants.

In summary, extensive variability has been seen in people with aphasia in terms of reported reading difficulty (Knollman-Porter et al., 2015; Parr, 1995; Samouelle, 2013), the difficulties seen on tests of reading comprehension (Meteyard et al., 2015; Webster et al., 2013) and the relationship between reading comprehension and relevant cognitive skills (Chesneau & Ska, 2015; Meteyard et al., 2015). We need to further understand reading

comprehension at paragraph/discourse level as this level of comprehension is related to everyday reading activities, for example, reading short newspaper/magazine articles, instructions and personal correspondence, and is a step towards developing our understanding of how we comprehend and integrate information across longer texts e.g., books. There is preliminary evidence, from previous research into spoken and written discourse comprehension, that information type influences comprehension in both healthy readers and people with aphasia, with a contrast between main ideas and details and stated and inferred information (e.g., Brookshire & Nicholas, 1993; Meteyard et al., 2015). However, previous studies have looked at these factors in a restricted number of participants and have not considered comprehension with paragraphs of varying length and complexity. There are a large number of text related factors that have not been investigated in people with aphasia and warrant further consideration. Variables of particular interest may be propositional content, lexical content, syntactic complexity and discourse length. Propositional content is a major factor influencing the readability of text for normal readers. Propositional density may impact the comprehension accuracy of people with aphasia due to the demands associated with extracting propositions, understanding the lexical items coding the propositions and understanding and remembering increased number of details. Readability formulas capture the differential difficulty of texts, considering the influence of both lexical and syntactic variables; many people with aphasia present with both lexical and grammatical impairments and readability (as defined by these formulas) may be sensitive to these difficulties. In healthy readers, the frequency of words is a strong predictor of readability (Kintsch & Van Dijk, 1978) and frequency/familiarity effects are prominent across a wide range of language tasks in people with aphasia (Whitworth, Webster, & Howard, 2014). From a syntactic point of view, readability formulas use very broad measures of complexity e.g., length of utterance. Length of utterance may not be sensitive to the specific difficulties that people with aphasia have with semantically reversible and syntactically complex sentences but similarly these sentences are not encountered frequently in everyday discourse.

When asked to rate reading difficulty, people with aphasia report more difficulty reading as the length of text increases; single words and sentences are easier than paragraphs which are in turn easier than books (Morris, Webster, Howard, Giles, & Gani, 2015). This perceived hierarchy may impact a person's willingness to attempt reading, including assessment and therapy activities. No studies have considered the effect of text/passage length on reading comprehension in people with aphasia. Length could have a beneficial impact on comprehension if it increases redundancy and the repetition of information. Alternatively, an increase in length may have a negative

impact on comprehension as longer texts contain more information and place increased demands on attention and memory. When reading extended text, ideas build over time and within a book or newspaper article, readers need to attach certain information or themes to particular characters. This may relate to the notion of updating the situational model (as investigated by Chesneau & Ska, 2015); as readers understand each paragraph, they must extract the key information and associate that key information with the characters and then as they read additional paragraphs, they must add extra information or change their situational model about the characters. There has been no attempt to study this type of information within previous studies of reading comprehension or reading assessments used with people with aphasia.

Aims

The current study aimed to contribute to our understanding of reading comprehension in people with aphasia; it investigated the effect of text variables on reading comprehension with a particular focus on length, readability, propositional content and type of information. It did this across a large group of participants (both people with aphasia and control participants), as part of a wider study of reading in people with aphasia (see Morris et al., 2015). The wider study investigated comprehension at single word and sentence level, oral reading and people's feelings about and attitudes towards reading). The following research questions were considered in the current study:

- Does the reading comprehension (paragraph level) of people with aphasia differ from that of healthy age-matched control participants?
- Is the reading comprehension of healthy control participants and people with aphasia influenced by the characteristics of the paragraph in terms of:
    - i) length
    - ii) readability
    - iii) propositional idea density?
- Is the reading comprehension of healthy control participants and people with aphasia influenced by the type of information to be understood? This included consideration of main ideas and details and inference (building on previous findings) but also the understanding of information built over time. It is difficult to test this aspect in a set of unrelated paragraphs, so in this study paragraphs were constructed around two sets of characters, with main ideas and themes related to those characters building over time. This type of information was described as 'gist' as it captures the overall meaning within each individual text.

Reading comprehension was considered both in terms of the accuracy in responding to questions tapping comprehension and reading time (the time taken to read paragraphs). It was predicted that, due to the everyday nature of the paragraphs designed for this study, control participants would read the paragraphs quickly and accurately; comprehension would not be significantly impacted by length, readability or propositional density as the complexity of the text should be within the capability of neurologically healthy readers of all abilities. It was predicted that some (but not all) people with aphasia would differ from control participants in terms of accuracy of comprehension. If there were people with aphasia who did not present with reading difficulties, the influence of text characteristics and type of information would be considered separately for the people with aphasia with and without reading difficulties. For people with aphasia who showed reading difficulties, it was predicted that accuracy of reading comprehension would be impacted by length, readability and propositional density, with worse performance on longer texts, texts with a higher (more complex) readability score and increased propositional density. People with aphasia would also present with reduced reading speed, which may be a more sensitive way of considering performance. However, it was anticipated that there would be variability between individuals and due to this variability, it may be difficult to identify specific effects of readability and propositional density on reading time; longer passages would of course take longer to read. In line with previous research, it was predicted that both groups would find main ideas easier than details and stated information easier to understand than information that needs to be inferred. It was thought that gist questions would be more difficult for both control participants and people with aphasia as they require integration of information across paragraphs, placing increased demands on both linguistic and cognitive processing.

Methods

Participants

Participants with aphasia (PWA) (n=75) were recruited alongside a group of healthy, age matched control participants (n=87). Control participants were recruited via advertisements to a range of organisations and volunteer pools, as well as to relatives of people with aphasia. The people with aphasia were recruited from a range of National Health Service (NHS) settings (via both speech and language therapy and stroke services) and from local aphasia support groups in England. The people with aphasia had a single symptomatic stroke resulting in aphasia (as confirmed by an experienced speech and language therapist on the basis of background language assessment and everyday communication). All participants completed a combination of comprehension and spoken production sub-

tests from the Comprehensive Aphasia Test (CAT, Swinburn, Porter, & Howard, 2004). To enable the study to consider the potential spectrum of reading performance, participants were recruited solely on the basis of having aphasia and did not have to report or present with reading difficulties. There was no cut-off in terms of upper or lower limit of time post-onset. Inclusion criteria for all participants included English as first language, no reported history of pre-morbid literacy difficulties, no reported or observed visual impairment and no significant (other) cognitive impairment (as measured by memory and attention probes).

Information about the participants can be found in table 1. The group of PWA was comprised of people who may or may not have reading comprehension difficulties. The group of PWA was subdivided into a group who showed reading comprehension impairment and those who did not; this was based on whether they were above or below the 5th percentile of the control participants for accuracy on the paragraph task used in the study. This gave a group of 40 participants whose reading comprehension fell within parameters of control subjects (in future, referred to as PWA: NRI (no reading impairment)) and 35 who were classified as impaired (PWA: RI (reading impairment)).

Insert table 1 about here

The control group, PWA: NRI and PWA: RI had a similar mean and range of educational level. They, however, differed in terms of the number of participants educated to a degree level. It is recognised that this may influence comparison across groups but the reading materials were pitched at a level significantly below degree level education (see below).

Materials

A set of 15 narrative paragraphs were developed specifically for this project. The paragraphs were designed to be of interest to a variety of readers and to be independent of particular domain/general knowledge. The paragraphs depicted everyday events e.g., holidays, shopping trips, involving two pairs of individuals: 'Sarah and Adam' and 'Aisha and Mary'. The aim was to produce readable and naturalistic text so manipulation of specific lexical items and syntactic structures was avoided. The paragraphs, therefore, resembled naturally occurring discourse where sentences can be interpreted via non-syntactic routes (Caplan & Evans, 1990).

Paragraphs varied in terms of length (number of words) and overall readability (as defined using the Dale-Chall readability score and grade, (Chall & Dale, 1995). The Dale-Chall Readability formula (Chall & Dale, 1995; Dale & Chall, 1948) takes into account both lexical and grammatical complexity as the calculation considers mean sentence length and the number of unfamiliar words. The propositional content of each paragraph was calculated using the

Computerized Propositional Idea Density Rater (CPIDR) 5.1 (Covington, 2012); CPIDR uses part of speech tagging, based on the premise that propositions correspond approximately to verbs, adjectives, adverbs, prepositions and conjunctions, and then readjustment rules to calculate propositional idea density. Paragraphs varied in terms of number of propositions (closely related to overall length) and propositional idea density, 'the number of expressed propositions divided by the number of words' (Brown et al., 2008, p542). A summary of the characteristics of the final paragraphs can be found in table 2. Contrasts in readability and propositional idea density were seen in paragraphs of between 30-80 words. There was a moderate correlation between readability and propositional density (r=0.596) reflecting the contribution of lexical measures. Both measures were included as readability also captured syntactic complexity. Two longer paragraphs at Dale-Chall grade 5-6 were included to look at the effect of increased length. Longer passages were not more complex in terms of either readability or propositional density. Longer paragraphs were not the primary focus of this study as these are tested within the DCT (Brookshire & Nicholas, 1993).

Insert table 2 about here

Each paragraph (except paragraphs 1 and 2) was followed by four written questions which aimed to consider comprehension of main ideas, details, stated and inferred information. The two shortest paragraphs only had two questions because of the limited information within them. Questions were generated around the information contained in each of the paragraphs. If information was repeated, these themes were classified as main ideas and if not repeated, they were classified as details. Stated questions used the information stated in the paragraph, with inferential questions requiring logical inferences based on word meanings, world knowledge or links across sentences. Questions types are defined in table 3. An example paragraph with the different types of information highlighted and the corresponding questions can be found in appendix 1. To avoid any requirements on verbal production, questions were presented in a sentence completion format with three response options: the target word or phrase and two distracter items. Distracters were plausible in general terms, but incorrect; distracters were not graded. Following all paragraphs, a set of questions assessed the understanding of gist across the paragraphs (see table 3); participants had to match a set of statements to the pairs of characters. Statements related to either both couples (e.g., they like holidays) or to one couple (e.g., they are very forgetful) and related to information presented and repeated across the paragraphs. Following initial development, the paragraphs and questions were piloted with both 11 control participants and 10 people with aphasia. Based on the performance of the control

participants, the pilot phase resulted in some changes to the wording of the paragraphs, the structure of some questions and the wording of some distracters. In addition, some of the gist questions were excluded. Pilot work with people with aphasia informed aspects such as duration of presentation.

Insert table 3 about here

Administration

Participants completed the test of paragraph comprehension within a single session, with paragraphs read consecutively. As part of the wider study, all participants also completed tests of written comprehension at single word and sentence level and tests of reading aloud at single word, sentence and paragraph level. In addition, the PWA completed background language and cognitive assessments and a questionnaire about reading (see Morris et al., 2015 for a full description of the wider study). The test was administered using a Dell Latitude touchscreen computer (E6430 ATG) running DMDX (Forster & Forster, 2003) allowing for consistent presentation and for recording of both accuracy and reading time. The paragraph was presented on the screen. Participants read the paragraph silently, the paragraph was removed and then a series of written questions were presented. Prior to the test, participants were told that they would read a series of paragraphs telling a story, with the stories becoming longer over time. They were told the stories would be about two pairs of individuals (and the names provided). They were encouraged to take their time and were made aware that the paragraph would disappear before questions appeared. They were also told that they would be asked some questions at the end about the characters in the stories.

Participants indicated when they had finished reading the paragraph, the tester then pressed the space bar to move the programme onto the questions and the time taken to read the paragraph was recorded. For all paragraphs reading time was truncated at 240 seconds; this was considered ample time to read the longest paragraph based on pilot data. For the written questions, the response time was recorded, taken from the person's selection (via touchscreen) of the response. If the participant did not produce a response within 20 seconds, the programme displayed the next item. Following all fifteen paragraphs, nine gist questions were presented**.** Participants were asked to think about the paragraphs which had been read and then match statements to the character pairs. Again, response was via touchscreen, to one of three options.

Results

Does the reading comprehension of people with aphasia differ from that of control participants?

Overall control participants performed well, with a mean proportion correct of .92 (SD = .06). In comparison, the group of PWA overall had a mean proportion correct of .77 (SD = .15). 40 participants were above the 5th percentile of the control participants and were classified as PWA: NRI (no reading impairment); 35 participants had performance below the 5th percentile and were classified as PWA: RI (reading impairment). Figure 1 shows the mean proportion correct for the groups of participants, including PWA overall. Subsequent graphs and tables show the PWA group split into PWA: RI and PWA: NRI. There was a significant difference in overall accuracy between the three groups ($F(2) = 2.05$, $p < .001$), with planned two sample t test comparisons showing significant differences between the controls and PWA:NRI ($t(125)=3.55$, $p=.001$), the controls and PWA:RI ($t(42.38)=14.80$, $p<.001$) and PWA:NRI and PWA:RI ($t(48.76)= 12.23$, $p<.001$).

Insert figure 1 about here

The average reading time for the three groups of participants for each of the 15 paragraphs is shown in figure 2. In all groups, there was significant individual variability. People with aphasia (both with and without reading comprehension difficulties) read more slowly than the control participants. On average, the control participants took 30 seconds to read approximately 100 words (SD = 10.87, range 10.96 to 73.23 seconds) (paragraph 14). The PWA took approximately double that time with PWA: NRI taking an average of 55 seconds (SD = 34.46, range 17.52 to 185.44 seconds) and PWA: RI taking 71 seconds (SD = 71.43, range 22.09 to 224.29). There was a significant difference in reading time for this paragraph between the three groups ($F(2) = 27.14$, $p < .001$), with planned two sample t test comparisons showing a significant differences between the controls and PWA:NRI ($t(42.61)=-4.51$, $p<.001$) and the controls and PWA:RI ($t(35.34)=-4.88$, $p<.001$). No significant difference was seen between PWA:NRI and PWA:RI ($t(77)= -1.64$, $p=.106$).

Insert figure 2 about here

Is the reading comprehension of control participants and people with aphasia influenced by the characteristics of the paragraph in terms of length, readability and propositional density?

Comprehension accuracy appears similar across the paragraphs, as shown in figure 3 (which provides the mean proportion correct for each of the paragraphs). Given that length increased across the paragraphs, this suggests that length did not influence accuracy. To examine whether this was the case and whether other aspects of the paragraph influenced comprehension, performance for control participants, PWA: NRI and PWA: RI was correlated with paragraph length (log N words), readability (the Dale-Chall score) and propositional idea density (using CPIDR-5.1). The results for comprehension accuracy are presented in table 4. Table 5 explores the relationship between text factors and overall reading time.

Insert figure 3 about here

Insert table 4 about here

Insert table 5 about here

After correcting for multiple comparisons using the Bonferroni formula, a p value of $p<.005$ was used to determine statistical significance. No significant correlation was found between reading comprehension accuracy and length, propositional density or readability of text, for all three groups. Unsurprisingly, there was a significant positive correlation between reading time and length across all of the groups. There was no significant correlation between reading time and either readability or propositional density. As it was important to consider relative reading time, the relationship between reading time in words per minutes (wpm) and readability and propositional density was also considered (table 6). For these comparisons, a corrected p value of $p<.008$ was used to determine statistical significance. Similar to above, no significant correlation between reading time and readability or propositional density was found. Further analysis of the individual contributions of the variables was not considered relevant.

Insert table 6 about here

Is the reading comprehension of healthy control participants and people with aphasia influenced by the type of information to be understood?

Performance across the groups was then analysed according to the type of information probed within the questions. Question types included main ideas stated (MIS), details stated (DS) main ideas inferred (MII), details inferred (DI) and gist. Figure 4 shows the proportion correct across question types for the three groups of participants.

Insert figure 4 about here

The effect of information type was considered by analysing the different question types following each passage and then a comparison of all questions assessing a single passage versus gist (information across passages). To look at the performance across different question types, a 3 x 2 x 2 ANOVA comparing between group (controls, PWA: NRI, PWA: RI) and within subjects for type of information (main idea, detail) and statement of information (stated, inferred) was carried out. Analysis showed a significant main effect of group ($F(2, 159) = 194.1$, $p < .001$), a significant main effect of type of information ($F(1,159) = 118.8$, $p<.001$) and a significant main effect of statement of information ($F(1, 159) = 40.9$, $p<.001$). There was a significant interaction between type of information and group ($F(2, 159) =11.1$, $p<.000$). There was no significant interaction between statement of information and group ($F(2, 159) = 1.8$, $p=.162$). The three way interaction (group x type of information x statement of information) just failed to reach significance ($F(2,159) = 2.9$, $p=.056$). All groups found main ideas easier than details, with the PWA: RI finding questions about details particularly difficult. All groups also found stated information easier than inferred information.

Although the PWA: NRI group are within the 5th percentile of the healthy control participants, there is evidence that they still differ on average from the control participants. When comparing the performance of only the controls and PWA: NRI, analysis showed a significant main effect of group ($F(1, 125) =10.4$, $p=.002$), a significant main effect of type of information ($F(1, 125) = 53.8$, $p<.001$) and a significant main effect of statement of information ($F(1, 125) =35.4$, $p<.001$). There was no significant interaction between type of information and group ($F(1, 125) =1.7$, $p=.190$) or between statement of information and group ($F(1, 125) = 3.1$, $p=.080$). The three way interaction (group x type of information x statement of information) was also not significant ($F(1,125) = 0.5$, $p=.481$). However, analysis also showed that the two groups of people with aphasia differed. When comparing the performance of PWA: NRI and PWA: RI, analysis showed a significant main effect of group ($F(1, 73) = 144.5$, $p<.001$), a significant main effect of

type of information (F (1, 73) = 66.7, p<.000) and a significant main effect of statement of information (F (1, 73) = 22.9, p<.001). There was a significant interaction between type of information and group (F (1, 73) = 6.7, p=.012). There was no significant interaction between statement of information and group (F (1,73) = 0.01, p=.915). The three way interaction (group x type of information x statement of information) was also not significant (F (1,73) = 3.6, p=0.062).

It was predicted that the gist questions would be more challenging for all participants than the other questions. To compare the performance across gist questions and all other questions, a 3 x 2 ANOVA comparing between group (controls, PWA: NRI, PWA: RI) and within subjects for question type (gist versus all other questions) was carried out. Analysis showed a significant main effect of group (F (2, 159) = 120.7, p <.001), a significant main effect of question type (F (1,159) = 123.5, p<.001) and a significant interaction (F (2,159) = 4.33, p=.015). Gist questions were harder for all groups, with PWA: RI finding them particularly difficult. When comparing the performance of control participants and PWA: NRI, there was a significant main effect of group (F (1, 125) = 8.9, p=.003), a significant main effect of question type (F (1, 125) = 68.3, p<.001) but no significant interaction (F (1,125) = 2.3, p=.136). When comparing the performance of PWA: NRI and PWA: RI, there was a significant main effect of group (F (1, 73) = 114.4, p<.001), a significant main effect of question type (F (1, 73) = 86.1, p<.000) and no significant interaction (F (1,73) = 1.4, p=.236).

Discussion

This study investigates reading comprehension at the paragraph level, considering performance across a large group of people with aphasia and of healthy age matched control participants. The impact of text related factors on both reading comprehension accuracy and reading time was examined. We will return to the questions the study posed and address each in turn within the discussion.

Does the reading comprehension (paragraph level) of people with aphasia differ from that of control participants?

The healthy control participants performed near to ceiling in terms of reading comprehension accuracy, with the exception of the gist questions, as was predicted. As a group, the people with aphasia had some difficulties with paragraph comprehension, with reduced accuracy when they answered questions about the passages. In line with predictions, within the people with aphasia, some performed within the 5th percentile of the control participants for

comprehension accuracy and were therefore classified as having no reading impairment. Although comprehension accuracy fell within the 5th percentile, the group of PWA: NRI still differed from the group of control participants, in both accuracy and reading time. There was a large difference between the mean performance of control participants (.92 correct) and the cut-off score for performance below the 5th percentile (.74 correct). In terms of reading speed, people with aphasia (both PWA: NRI and PWA: RI) read much slower than the control participants and did not differ significantly from each other. This is consistent with previous research where people with aphasia have reported concerns about reduced reading speed (Knollman-Porter et al., 2015; Samouelle, 2013) and with previous studies which have seen reduced reading speed on tests of paragraph comprehension (e.g., Webster et al., 2013). This study suggests that considering accuracy alone may be insufficient and that it is important to consider both reading time as well as accuracy when determining difficulty. It is also crucial to investigate the person's own perception of their reading (Parr, 1995; Webster et al., 2013). All three aspects combine in determining whether intervention is relevant, possible approaches and how change is perceived and assessed. The variability in reading in healthy individuals (in terms of both ability and speed) also needs consideration.

Is the reading comprehension of control participants and people with aphasia influenced by the characteristics of the paragraph in terms of length, readability and propositional density?

Overall as predicted, comprehension of these texts was within the capability of healthy readers and there were no significant effects of length, readability or propositional density on the accuracy of comprehension for control participants. Whilst people with aphasia did experience difficulties with the text there was, perhaps surprisingly, the same lack of significant effect of length, readability or propositional density on the accuracy of comprehension. Readability and propositional density were contrasted in paragraphs of 30-80 words; two longer paragraphs of 100 and 250 words were included to consider length. As the length of the paragraph increased, there was no reduction in comprehension accuracy. This would suggest that the increased number of propositions and the memory demands related to individual passages did not significantly impact performance; increasing length further may of course impact this finding. As the paragraphs were stories, with the development of events over time, the redundancy and repetition within the paragraphs may have been important in supporting comprehension and overall, this may account for the performance across the task. In contrast to predictions, there was no significant effect of readability grade on comprehension accuracy. The range of passage grades had been chosen to reflect everyday reading texts, with grade 5-6 considered to be functional for adult readers (Brookshire & Nicholas, 1993). It is possible that an

effect of readability would have been found if there had been a broader range of readability grades (i.e., more complex passages) but this would not be reflective of most everyday reading material. It is also important to consider what the readability grade captures; this broad measure of sentence length and lexical content may not be sufficiently sensitive to the difficulties many people with aphasia experience. Within the paragraphs, there was no attempt to include particular sentence types that people with aphasia generally find difficult e.g., semantically reversible passives or object clefts (Caplan & Evans, 1990; Levy et al., 2012). Everyday discourse contains sentences that can normally be understood via lexical information or discourse constraints (i.e., without explicit understanding of grammatical structure) (Caplan & Evans, 1990) and it was important to mirror this within the assessment paragraphs. There was also no significant effect of propositional idea density on comprehension accuracy. The passages were written to be coherent and interesting, with the number and density of propositions then calculated. This gave a small range of propositional density (0.41-0.57) across the paragraphs. The length of the passage significantly impacted overall reading time.

Is the reading comprehension of healthy control participants and people with aphasia influenced by the type of information to be understood?

This study investigated comprehension of different types of information via questions following the paragraphs. This off-line investigation is consistent with current clinical assessments of reading although it is recognised it places demands on memory as well as comprehension. Type of information influenced comprehension. Questions about main ideas were easier than questions about details for both control participants and people with aphasia. This finding is consistent with previous research into both spoken and written comprehension (Brookshire & Nicholas, 1984, 1993; Meteyard et al., 2015; Wegner et al., 1984). The PWA: RI found questions about details particularly difficult. This suggests that the repetition and prominence of main ideas supports comprehension, with isolated details being more difficult to understand and/or remember. Similarly, both control participants and people with aphasia also found questions about stated information easier than inferred information. This is consistent with the contrast seen between explicitly and implicitly stated written information (Brookshire & Nicholas, 1993) although in contrast to our study, lexical synonyms (i.e., same meaning but different words) were defined as stated information within the Brookshire and Nicholas study. The findings are also consistent with the Meteyard et al. (2015) study which identified difficulties with inference, reflected either in the contrast between factual and inferred information or specific difficulties with either local or global inferences. Within the current study, questions about inferred

information included a combination of logical and bridging inferences. In answering questions, participants were not being asked to make elaborative inferences but for some questions, people could draw on world knowledge to support the understanding of the other types of inference. For example, when asked to infer that it was winter based on the statement 'hills cloaked deep with snow', 'winter' may be related to the lexical meaning of 'snow' but the person also can use wider world knowledge about the relationship between snow and winter to answer the question. For all participants, making inferences requires increased processing demands, potentially resulting in reduced comprehension accuracy overall.

This was the first study of reading comprehension in people with aphasia to consider the comprehension of information built up over time. The questions about the characters defined as 'gist' required integration of information across the 15 paragraphs, with questions generally drawing on information stated or inferred across two to three paragraphs. As predicted, gist questions introduced a level of difficulty for participants in all groups. For control participants, this was the only aspect where they experienced difficulty with accuracy. The PWA: RI group found these questions particularly hard with performance for many participants being at the level of chance. There are multiple reasons why this type of information may be difficult for readers. The questions require people to correctly attach information to one of the pairs of characters and add to this information as they read more, updating their situational model; this places additional demands on both linguistic processing and storage within episodic memory. Reading and remembering information across paragraphs also requires sustained attention. The gist questions begin to explore how we build our understanding of text over time. However, the relationships between main ideas within a single text and gist across tests, how long information can be retained and exactly how these gist questions relate to everyday reading needs further investigation. Exactly how these gist questions relate to everyday reading requires further consideration (for example, do they relate to establishing information about themes or characters in a text) but nevertheless they begin to explore how we build our understanding over time.

Conclusions

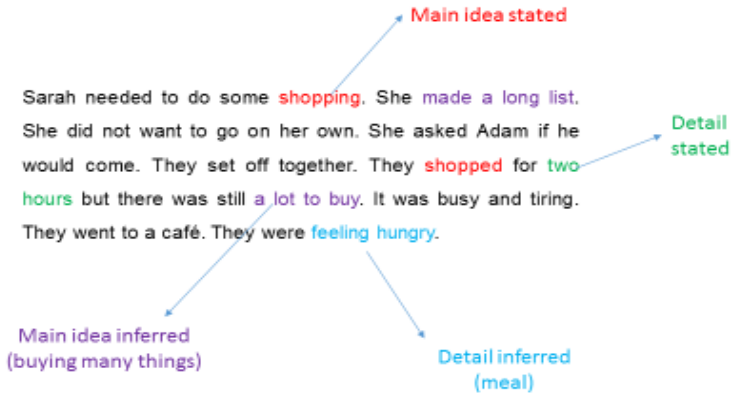
This study has contributed to our understanding of the importance of text related variables when considering reading comprehension. It also highlights the importance of considering comprehension of naturalistic texts; naturalistic text may not always be sensitive to the specific linguistic difficulties people with aphasia experience when lexical or sentence comprehension is assessed, but is more representative of everyday reading. This study also highlights the importance of not only measuring accuracy but also reading time or speed, and the sensitivity of this.

Some people with aphasia may not demonstrate difficulties as measured by comprehension accuracy data but difficulties may be revealed when reading time is considered. Along with the person's perceptions, this will have implications for whether intervention is indicated or not, potentially for the direction of therapy, for measurement of change and what constitutes improvement. The study raises questions about how to determine whether reading comprehension and reading speed for an individual person with aphasia differs from healthy readers considering that reading ability is variable. Anecdotally, many people with aphasia were surprised that they could understand some of the information within the paragraphs despite significant difficulties with the comprehension of single words and sentences. The outcome of this study challenges assumptions (held by both people with aphasia and potentially clinicians) that paragraphs are harder than shorter segments of text and that difficulty increases with increasing length of paragraph. Certainly within this type of text, redundancy and repetition of information seemed to support comprehension, particularly for main ideas. This does not detract from a potential influence of confidence in ability; in this study readers began with (very) short paragraphs, with these increasing over time; this may have contributed to their perception of ability and willingness to attempt the task. The study shows that reading comprehension is influenced by the type of information to be understood. People with aphasia were better able to understand main ideas than details and stated than inferred information. This can be considered further in terms of the type of comprehension required to understand particular genres of text and this could be utilised within intervention. For certain genres of text, facilitating understanding of those main ideas could be most beneficial and for other types of text, strategies to ensure comprehension of relevant detail could be more helpful. The important finding that establishing meaning over time was particularly difficult for people with aphasia also requires further consideration, given the relevance of this for many reading activities.

Reading is an important everyday activity which plays a key role for participation in social and work domains for many individuals. It is clear that reading comprehension is impaired for many people with aphasia, but not necessarily all. We need to consider the complexities of reading, of different genres, the purpose of reading, individual reading ability and preferences and relationships between different reading skills. This study contributes an important part of the jigsaw in this fascinating and complex puzzle.

Appendix 1

4.



	Questions	TARGET	DISTRACTER 1	DISTRACTER 2
MIS	Sarah and Adam went	shopping	for a walk	to the cinema
DS	They shopped	for two hours	all morning	for four hours
DI	They stopped to get	a meal	a drink	more money
MII	Sarah needed to buy	many things	a few things	a present

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Table 1: Background information about participants

	Controls	**PWA: NRI**	**PWA: RI**
n	87	40	35
Gender	34 men 53 women	22 men 18 women	21 men 14 women
Age	Mean = 62.9 years (range 41-89)	Mean = 62.2 years (range 41-84)	Mean = 68.5 years (range 38-87)
Years of Education[1]	13.4 years (range 9-17) 46 participants educated to degree level	12.5 years (range 9-16) 12 participants educated to degree level	11.2 years (range 9-16) 5 participants educated to degree level
Time post-onset	n/a	4.4 years (range 2 months to 21 years)	3.7 years (range 3 months to 15 years)

[1] Years of education was calculated by school leavers age, minus 5 (to reflect school start age) with plus three years for degree or equivalent qualification.

Table 2: Characteristics of paragraphs

Paragraph	Number of Words	Number of Sentences	Dale Chall Score	Dale Chall Grade	Propositional Idea Density	Propositional Ideas
1	36	6	4.8	4	0.44	16
2	33	6	5.3	5-6	0.46	15
3	56	9	4.9	4	0.41	23
4	58	9	5.9	5-6	0.51	32
5	48	8	6	7-8	0.50	24
6	53	3	6.6	7-8	0.57	30
7	46	7	7.7	9-10	0.52	24
8	72	7	5.2	5-6	0.46	33
9	62	7	4.8	4-5	0.51	31
10	71	12	5.9	5-6	0.55	39
11	73	7	6.1	7-8	0.53	39
12	71	4	6.7	7-8	0.52	37
13	79	5	7.6	9-10	0.47	37
14	104	7	5.9	5-6	0.52	53
15	253	32	5.4	5-6	0.49	124
Mean	74.3	8.6	5.9		0.49	37.1
Range	33-253	3-32	4.8-7.7		0.41-0.57	15-124

Table 3: Question Types

Question Type		**Definition**
Main Idea Stated	MIS	Question about an idea that is present in the paragraph and repeated or elaborated.
Detail Stated	DS	Question about an idea that is present in the paragraph but not repeated or elaborated. Within the question, the detail could be worded in the same way, could involve a synonym e.g., quiet/tranquil or a simple word association e.g., wet/rain.
Main Idea Inferred	MII	Question about information which is inferred from a stated main idea. This could require a logical inference based on word meaning, an inference bridging information across sentences or a link with world knowledge.
Detail Inferred	DI	Question about information which is inferred from a stated detail. This could require a logical inference based on word meaning or a link with world knowledge e.g., stated detail 'snow' allows an inference of 'winter'.
Gist		Question about the characters where information/themes are built across the paragraphs.

Table 4: Correlations between comprehension accuracy (proportion correct) and contrasting factors of paragraphs

	Proportion Correct & Length	**Proportion Correct & Readability**	**Proportion Correct & Propositional Density**
Controls	r = 0.031 p = .544	r = -0.437 p = .052	r = 0.217 p = .781
PWA: NRI	r = -0.087 p = .379	r = -0.138 p = .312	r = 0.250 p = .816
PWA: RI	r = -0.157 p = .288	r = 0.058 p = .581	r = 0.150 p = .703

Results needed to be significant at p<.005 following Bonferroni correction for multiple comparisons.

Table 5: Correlations between overall reading time and contrasting factors of paragraphs

	Overall Reading Time & Length	**Overall Reading Time & Readability**	**Overall Reading Time & Propositional Density**
Controls	r = 0.951* p = <.001	r = 0.026 p = .926	r = 0.201 p = .473
PWA: NRI	r = 0.961* p = <.001	r = 0.040 p = .888	r = 0.218 p = .434
PWA: RI	r = .959* p = <.001	r = 0.100 p = .724	r = 0.266 p=.338

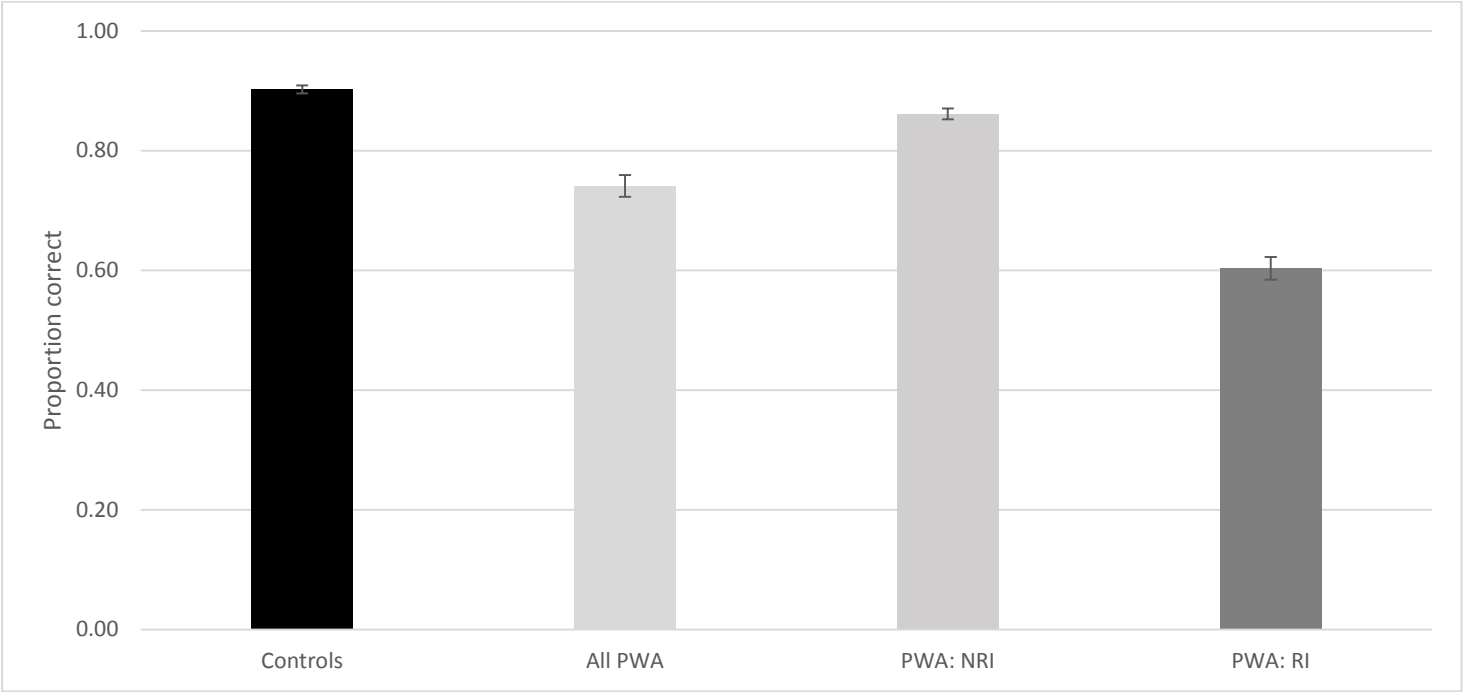
* Significant. Results needed to be significant at p<.005 following Bonferroni correction for multiple comparisons.

Table 6: Correlations between reading time (words per minute (wpm)) and contrasting factors of paragraphs

	Reading Time (wpm) & Readability	**Reading Time (wpm) & Propositional Density**
Controls	r=-0.408 p = 0.131	r = -0.478 p = 0.072
PWA: NRI	r = -0.454 p = 0.089	r = -0.602 p = 0.018
PWA: RI	r = -0.293 p = 0.290	r = -0.249 p = 0.372

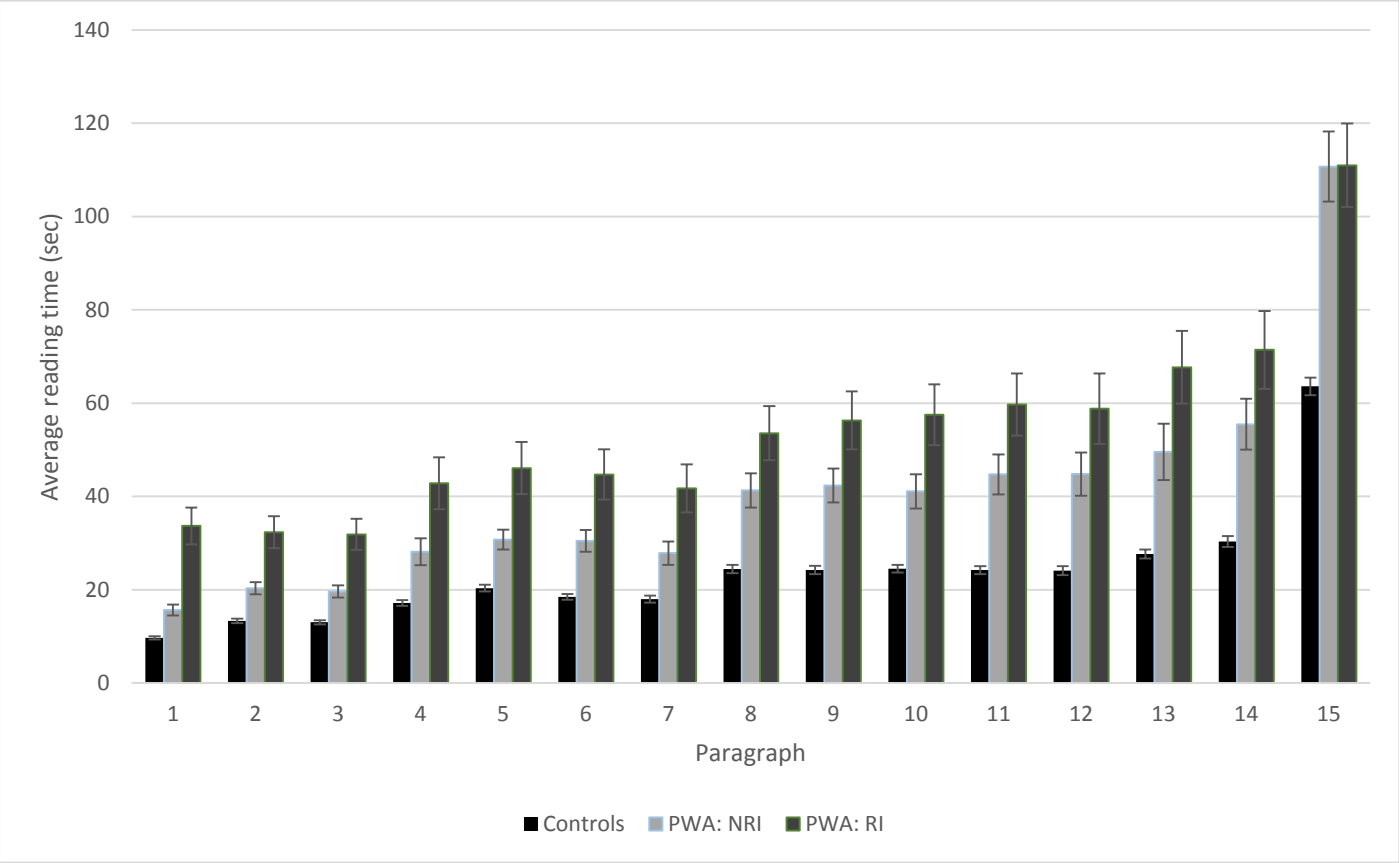
Results needed to be significant at p<.008 following Bonferroni correction for multiple comparisons.

Figure 1: Mean proportion correct (across all question types)



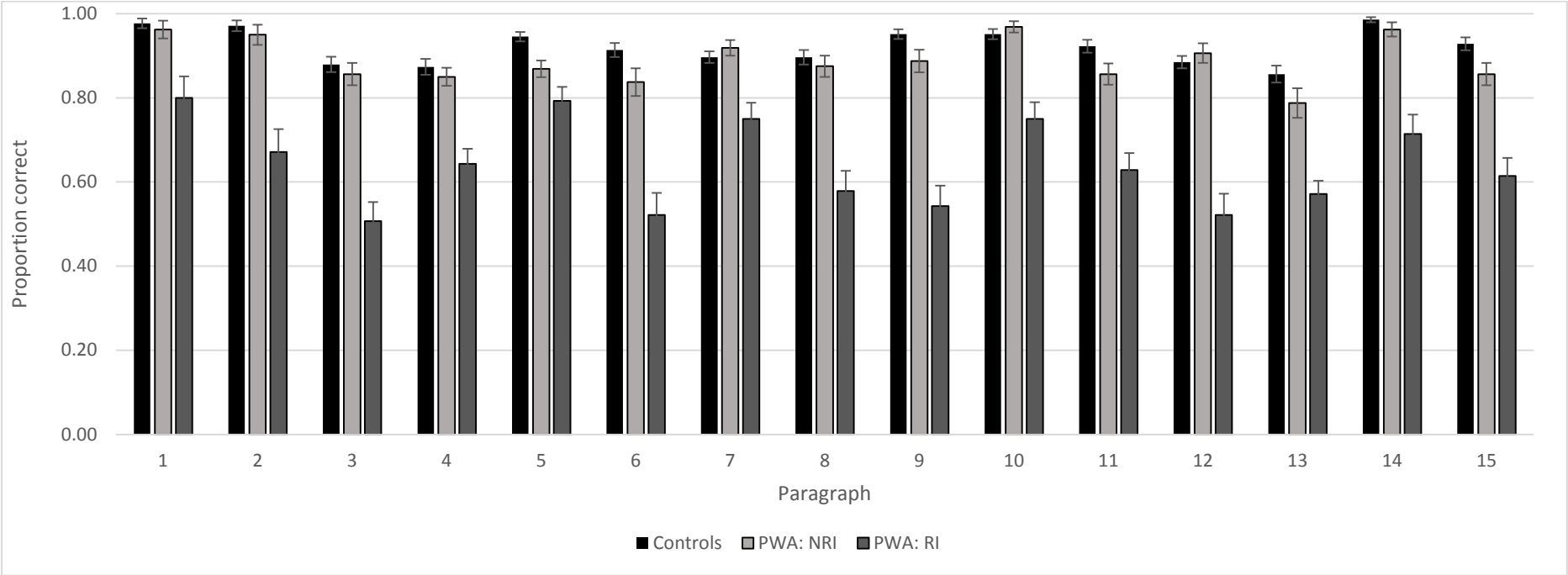
Error bars show standard errors of the mean.

Figure 2: Mean reading time for each of the paragraphs



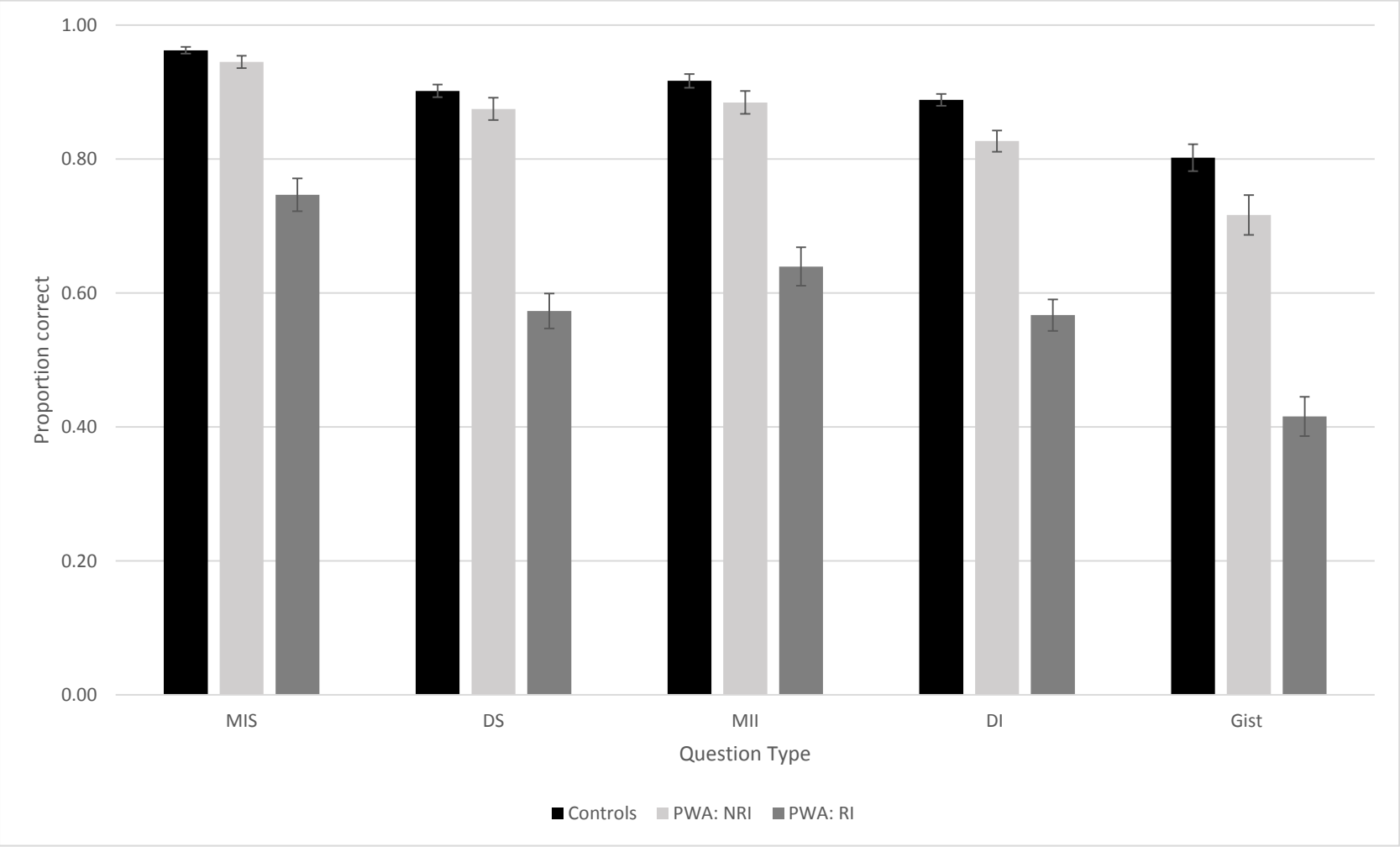
Error bars show standard errors of the mean.

Figure 3: Mean proportion correct for each of the paragraphs



Error bars show standard errors of the mean.

Figure 4: Mean proportion correct for questions assessing different types of information



Error bars show standard errors of the mean.